



Rec'd 22 APR 2005

90/532336
1GB 2003 70.03641



INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

REC'D 21 NOV 2003

WIPO PCT

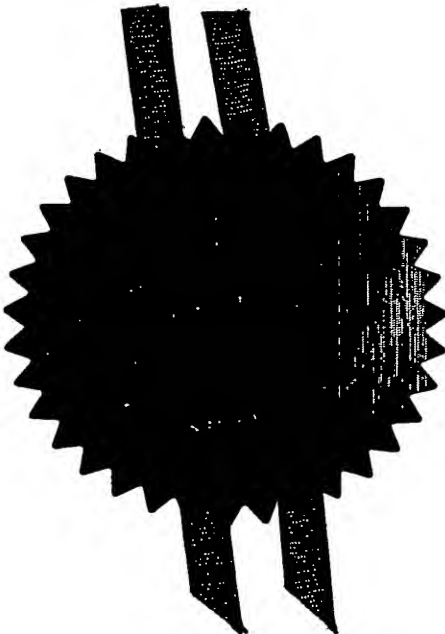
**PRIORITY
DOCUMENT**
SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH RULE 17.1(a) OR (b)

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.



Signed *AmBrewster*

Dated 11 November 2003



1/77
08JUL03 EB20738-2 D02246
P01/7700 0.00-0315858.1

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP10 8QQ

1. Your reference

P015879GBR DAA JOF

2. Patent application number

(The Patent Office will fill in this part)

0315858.1

3. Full name, address and postcode of the or of each applicant (*underline all surnames*)

Porvair Filtration Group Limited
Clywedog Road South
Wrexham
LL13 9X3

Patents ADP number (*if you know it*)

866539002

If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom

4. Title of the invention

Process

5. Name of your agent (*if you have one*)

D Young & Co

"Address for service" in the United Kingdom to which all correspondence should be sent (*including the postcode*)

21 New Fetter Lane
London
EC4A 1DA

Patents ADP number (*if you know it*)

59006 ✓

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (*if you know it*) the or each application number

Country

Priority application number
(*if you know it*)

Date of filing
(*day / month / year*)

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing
(*day / month / year*)

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (*Answer 'Yes' if:*

Yes

- a) any applicant named in part 3 is not an inventor, or
 - b) there is an inventor who is not named as an applicant, or
 - c) any named applicant is a corporate body.
- See note (d))

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form 0

Description 20

Claim(s) 5

Abstract 1

Drawing(s) 1-1

10. If you are also filing any of the following, state how many against each item.

Priority documents 0

Translations of priority documents 0

Statement of inventorship and right to grant of a patent (Patents Form 7/77) 0

Request for preliminary examination and search (Patents Form 9/77) 0

Request for substantive examination (Patents Form 10/77) 0

Any other documents 0
(please specify)

11.

I/We request the grant of a patent on the basis of this application.

Signature *D Young & Co*
D Young & Co (Agents for the Applicants)

Date 7 July 2003

12. Name and daytime telephone number of person to contact in the United Kingdom

David Alcock

023 8071 9500

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

- If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.
- Write your answers in capital letters using black ink or you may type them.
- If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.
- If you have answered 'Yes' Patents Form 7/77 will need to be filed.
- Once you have filled in the form you must remember to sign and date it.
- For details of the fee and ways to pay please contact the Patent Office.

PROCESS

The present invention relates to a functionalised porous material and a process for the preparation of a functionalised porous material.

5

BACKGROUND ART

The separation techniques of solid phase extraction and chromatography have utilised the materials silica and polystyrene in specially prepared powder forms as adsorbent media. In more recent years, drug discovery programmes have required rapid synthesis of biologically active organic molecules using similar powders. Combinatorial chemistry is one approach for producing libraries of such molecules and solid phase synthesis is one of the preferred techniques used. In all of these applications the loose powder used can create handling problems with device assembly, performance and ease of use.

15

The solid phase extraction (SPE) applications utilise cartridges and well plates with the loose powder contained with them between two porous frits. An exact dose of the powder must be contained between the porous frits and device assembly in these applications can be problematic. The assembly process requires the insertion of a porous frit into the bottom of the micro-titre plate followed by the introduction of the sorbent powder, usually in the form of a slurry, and then the insertion of a second porous frit on top of the powder. The assembled micro-titre plate must then be dried out before it can be packaged ready for use. There may be additional drawbacks to applications that utilise loose powder. For example, the powder may be driven into the porous frit by liquids, thus blocking the cartridge. Poor performance may also result from flow channels being developed through the powder by the liquids (channelling).

20

Companies such as 3M and Merck have developed methods of immobilising the powder on inert substrates to alleviate this problem. For example, US 6,475,340 discloses a solid phase extraction sheet material that includes a porous matrix with an active particulate entrapped therein. The active particulate exhibits reactive and/or sorptive properties towards the chemical species to be removed. The sheet material may be used in a cartridge device. US 6,492,183 discloses multi-layer extraction articles having two porous support layers with a solid phase extraction (SPE) medium comprising a fluoropolymer between them. The fluoropolymer SPE medium may be in a variety of

30

35

forms including a membrane that includes a fibril matrix and sorptive particles enmeshed therein.

5 The problems faced in solid phase synthesis (SPS) differ from those of solid phase extraction. Chemists need to make large numbers of different molecules for drug screening programmes. Weighing out adsorbent powders and then filtering them from the reactants or solvents can be time consuming, especially when large numbers of separate reactions are being carried out. Companies such as Irori and Millennium Pharmaceuticals have addressed this problem by containing the powders in specialised
10 packages. However, these packages are reported to have their own limitations in terms of difficulty of manufacture, poor reproducibility or low chemical activity.

WO/0021658 discloses a porous device for use in a method of synthesis comprising a body having an internal region which is porous wherein an active material, for example a
15 solid support resin, is entrapped within the internal region. A typical example of this device is a functionalised resin encapsulated within a porous polyethylene plug.

The present invention alleviates the problems of the prior art.

20 In one aspect the present invention provides a process for the preparation of a functionalised porous material comprising the steps of sintering polymer components to provide a porous substrate and grafting a chemical species selected from a molecularly imprinted polymer and a functionalised moiety onto the porous substrate to provide the functionalised porous material; wherein when the polymer components are a polymer
25 powder and the chemical species is a functionalised moiety, the chemical species is grafted using pulsed plasma polymerisation.

In another aspect the present invention provides a functionalised porous material comprising (i) a porous substrate comprising a body having an external surface and
30 pores extending from the external surface into the body, wherein the pores define an internal surface and (ii) a molecularly imprinted polymer; wherein the molecularly imprinted polymer is attached to the external surface and/or the molecularly imprinted polymer is attached to the internal surface of the porous substrate.

The functionalised porous material of the present invention may advantageously be utilised in solid phase extraction applications. Use of the present invention typically eliminates many of the problematic manufacturing steps required in the prior art to provide cartridges and well plates for SPE. The functionalised porous material is further
5 advantageous because it does not suffer from the prior art problems associated with use of loose powder such as blocking of the porous frits and channelling. Furthermore use of the present invention reduces the hold up volume of the device.

The functionalised porous material of present invention may also be utilised in solid
10 phase synthesis. Unlike the prior art, the present invention does not require that a functionalised resin be encapsulated within a porous device. Thus the need for encapsulation steps during manufacture are removed. The functionalised porous material typically has a functionalised external and/or internal surface and is thus a highly convenient material typically having a specific chemical activity. The functionalised
15 porous material may, for example, be used as a scavenger. In this application it may be added to a reaction vessel and then removed following clean up advantageously allowing the reaction to be taken to the next stage. In another embodiment, the functionalised porous material may be used in synthesis. It may advantageously be transferred from one reaction to the next without the need for a filtration step.

20 The shape, pore structure and type and degree of functionalisation of the functionalised porous material may all be selected such that the functionalised porous material is suitable for any one of a wide range of applications. The functionalised porous material is typically highly suitable for use in high throughput applications involving a high degree
25 of automated handling. The functionalised porous material of the present invention may advantageously be utilised in numerous applications including SPE, SPS, catalysis, sensors, assays and drug delivery.

In some embodiments, the present invention may comprise a porous substrate of the
30 material typically used in the prior art for porous frits. This porous substrate is functionalised to provide the functionalised porous material which may be used to carry out solid phase separation directly.

For ease of reference, these and further aspects of the present invention are now
35 discussed under appropriate section headings. However, the teachings under each

section are not necessarily limited to each particular section.

PREFERRED EMBODIMENTS

5 PROCESS

As previously mentioned, the present invention provides a process for the preparation of a functionalised porous material comprising the steps of sintering polymer components to provide a porous substrate and grafting a chemical species selected from a molecularly
10 imprinted polymer and a functionalised moiety onto the porous substrate to provide the functionalised porous material; wherein when the polymer components are a polymer powder and the chemical species is a functionalised moiety, the chemical species is grafted using pulsed plasma polymerisation.

15 The term "sintering" as used herein means heating to a temperature below the melting point of the polymer components, optionally under pressure, such that the polymer components form a single coherent body.

The term "polymer components" as used herein means compounds obtainable by
20 polymerisation of monomer units. The polymer components of the present invention may be in any suitable form including powder, pellet, or fibre.

The term "porous substrate" as used herein means a body having an external surface and pores extending from the external surface into the body, wherein the pores define an
25 internal surface.

The term "molecularly imprinted polymer" is well understood in the art. It is understood to mean a material comprising imprint sites obtainable by polymerisation of monomer units, wherein the imprint sites are regions of the 3-dimensional structure of the material
30 which are complementary to a specific template molecule.

The term "functionalised moiety" as used herein means a chemical species other than a molecularly imprinted polymer, comprising at least one functional group.

The term "pulsed plasma polymerisation" as used herein means exposing a substrate to a pulsed plasma field through which vaporised monomers pass, such that the vaporised monomers bond to the substrate to form a polymer chain.

5 Polymer components

In one aspect, the polymer components are polyolefin components.

Examples of suitable polyolefins include ethylene vinyl acetate, ethylene methyl acrylate, polyethylenes, polypropylenes, ethylene-propylene rubbers, ethylene-propylene-diene rubbers, poly(1-butene), polystyrene, poly(2-butene), poly(1-pentene), poly(2-pentene), poly(3-methyl-1-pentene), poly(4-methyl-1-pentene), 1,2-poly-1,3-butadiene, 1,4-poly-1,3-butadiene, polyisoprene, polychloroprene, poly(vinyl acetate), poly(vinylidene chloride), poly(tetrafluoroethylene), poly(vinylidene fluoride) and acrylonitrile-butadiene-styrene.

In a preferred aspect, the polymer components are polyethylene components or polypropylene components, preferably polyethylene components.

Polyethylene is typically characterised by its density and low density polyethylene (LDPE), high density polyethylene (HDPE) and ultra high molecular weight polyethylene (UHMWPE) may all be used in the present invention. Preferably the polyethylene components are HDPE components.

In one aspect the polymer components are a polymer powder. In a preferred aspect, the polymer components are a polyethylene powder. In a highly preferred aspect, the polymer components are an HDPE powder.

Preferably the polymer components are sintered in a mould.

In one preferred embodiment, the polymer components are sintered in a compression mould. In this embodiment, the mould is charged with the polymer components, heated to the sintering temperature of the polymer components, allowed to equilibrate and then subjected to pressure. The amount of pressure and the nature in which the pressure is applied may be used to control the properties of the porous substrate, such as the void

volume and the pore size. The pressure typically ranges from about 1 psi to about 10psi, depending on the nature of the polymer components and the desired porosity of the porous substrate. In general, the greater the pressure applied to the mould, the smaller the average pore size and the greater the mechanical strength of the final product. The
5 duration of time during which the pressure is applied also varies depending on the desired porosity of the porous substrate and is typically from about two to about ten minutes, preferably from about four to about six minutes.

Once the porous substrate has been formed, the mould is allowed to cool. The cooling
10 may take place while the pressure is being applied or once the pressure has been removed. The porous substrate is then removed from the mould.

The mould may be any suitable shape. In a preferred aspect the mould is cylindrical or rectangular prismatic. More preferably the mould is cylindrical.

15 In another preferred aspect, the polymer components are polymer fibres. Preferably in this aspect the polymer fibres are sintered to provide a matrix.

Porous Substrate

20 The porous substrate may be any suitable shape, such as a cube, sphere, cylinder, rod, sheet, disc, membrane or film. In one preferred aspect the porous substrate is cylindrical or rectangular prismatic, i.e. plug-shaped or tablet-shaped. The shape of the porous substrate may be determined by the shape of mould used in the sintering process and
25 may be selected according to the desired application of the functionalised porous material. For example, the porous substrate may have a shape suitable for use in a conventional micro-titre plate, SPE cartridge or other such device.

As previously mentioned, the porous substrate is a body having an external surface and
30 pores extending from the external surface into the body, wherein the pores define an internal surface.

The presence of the pore structure within the porous substrate is highly advantageous because of the increased surface area. In one embodiment, the present invention
35 provides a functionalised porous material comprising a functionalised external surface

and a functionalised internal surface and which thus has an increased functionalised surface area as compared with a non-porous material. The functionalised internal surface may be easily accessed through the pore structure.

- 5 The choice of polymer components typically influences the nature of the porosity of the porous substrate, such as the pore structure and pore size and its internal surface area. In particular, the size and shape of the chosen polymer components are important. The physical characteristics of the porous substrate can therefore be controlled and modified according to the desired final use of the functionalised porous material. This ability to
10 tailor the pore structure can minimise hold up volume for SPE and SPS applications or provide the optimum flow path for a sensor or bio-reactor.

- Preferably the porous substrate comprises a plurality of interconnected pores on a larger-than-molecular scale. Preferably the porous substrate is permeable, in that the
15 pores are interconnected to allow fluid flow from the external surface into an adjacent region in the body, and from one adjacent region to another. Preferably, the pores are interconnected so that fluids may flow throughout the porous substrate.

- The pores may be isotropic or anisotropic, and may be non-directional or unidirectional.
20 The pores may be connected by a so-called tortuous path, which essentially means that the pore channels are randomly directed through the article in a non-directional manner.

- However, the pores need not be interconnected but instead may be separate from one another. For example, the pores may be separate from one another but extend
25 completely through the porous substrate, or the pores may terminate within the porous substrate ("non-through" pores). However, the pores should be accessible to fluids that contact the external surface of the porous substrate, i.e., the porous substrate should not comprise only pores that are isolated from the external surface.

- 30 The porosity of the porous substrate may be characterised in terms of pore diameter and void volume.

- The pores typically have effective diameters larger than about 0.01 microns (1 angstrom), preferably at least about 1 micron up to about 2000 microns, and more
35 preferably from about 10 to about 1000 microns. The porous substrate may be micro-

porous, in which case the pores have a pore size in the range between about 0.05 and about 20 microns. The porous substrate may be macro-porous, in which case the pores have a pore size of about 20 microns to about 2000 microns, preferably about 20 to 500 microns. A preferred porous substrate has a nominal pore size of about 1 to about 50
5 microns. Porosity may be determined according to ASTM D276-72, and pore size distribution may be determined according to ASTM F316-70.

The porosity of the porous substrate can also be characterised in terms of void volume. The void volume is defined as the volume within the porous substrate that would be
10 accessible to a fluid that entered the porous substrate. Thus, the porosity may be defined as the void volume divided by the total volume of the porous substrate. Porous substrates of any void volume from 1% to 90% may be used in the present invention. Preferred porous substrates have a void volume of about 10% to about 90%, more preferably about 20% to about 80%, more preferably about 30% to about 70%, and still
15 more preferably about 35% to about 60%.

Molecularly Imprinted Polymer

As previously mentioned, the process of the present invention comprises the step of
20 grafting a chemical species selected from a molecularly imprinted polymer and a functionalised moiety onto the porous substrate.

Preferably the molecularly imprinted polymer is capable of interacting with a species selected from the group consisting of a metal ion, a toxin, a pharmaceutical compound
25 and a microbial organism.

In a preferred aspect, the molecularly imprinted polymer is capable of immobilising a species selected from the group consisting of a metal ion, a toxin, a pharmaceutical compound and a microbial organism.
30

A molecularly imprinted polymer of the present invention may be used to trap and immobilise chemical species or biological organisms either for detection or to render them inoperative thereby acting as a protection device.

Molecularly imprinted polymers of the present invention may be produced by any suitable method. A preferred method is described below.

As previously mentioned, the term "molecularly imprinted polymer" as used herein
5 means a material comprising imprint sites obtainable by polymerisation of monomer units, wherein the imprint sites are regions of the 3-dimensional structure of the material which are complementary to a specific template molecule.

The first step in the production of a molecularly imprinted polymer typically involves the
10 provision of a reaction mixture comprising monomer units and a template molecule. This reaction mixture may optionally comprise other agents such as a polymerisation initiator, and a homogenisation agent. The homogenisation agent aids the even dispersion of the template molecule throughout the reaction mixture.

15 It will be appreciated by those skilled in the art that the term "template molecule" is not limiting and may include, for example, low molecular weight molecules, high molecular weight molecules such as polymers, synthetic and naturally-occurring molecules, metal ions and even microbial organisms.

20 The next step is the polymerisation of the reaction mixture. This may be carried out in any suitable manner. Typically the polymerisation is initiated by irradiating the reaction mixture with ultra-violet light. Alternative ways to initiate polymerisation include heating and/or the use of a chemical polymerisation initiator. During polymerisation the liquid reaction mixture is converted into a polymer mass containing the template molecules
25 dispersed throughout. Following initiation the monomers link together to form a solid. The monomers seek the tightest configuration possible as they solidify around the template molecules. As a result, the polymer mass contains a large number of the template molecules that are each tightly surrounded by the polymer mass.

30 The template molecules have a unique 3-dimensional shape, and so they form cavities or pockets throughout the polymer mass that surrounds and contains them. As such, the polymer mass is a formation of a molecularly imprinted polymer (MIP), that is imprinted to the template molecules that it contains. Typically a very large number of the template molecules are contained in the polymer mass.

The next step typically involves grinding, pulverising, or fracturing the polymer mass into a plurality of polymer fragments each of which typically contains many template molecules. Many of the template molecules are at the surface of the polymer fragments but some are surrounded by and therefore contained within the fragments. The template molecules at the surface of the polymer fragments must be removed to expose the imprint sites.

Depending upon the desired final application, the polymer fragments may have any desired range of sizes (diameters). The finer the polymer fragments are, the greater will be the resultant surface area. A greater surface area is usually desirable because more imprint sites are exposed. Therefore, a smaller (finer) granulation of the polymer fragments will, generally, improve the efficiency of the final application. However, there are situations where a larger diameter or coarser size for the polymer fragments is desirable. The polymer fragments preferably have a diameter of $0.1\mu\text{m}$ to $200\mu\text{m}$, preferably $1\mu\text{m}$ to $200\mu\text{m}$, more preferably $10\mu\text{m}$ to $200\mu\text{m}$, such as $10\mu\text{m}$ to $100\mu\text{m}$, such as $10\mu\text{m}$ to $50\mu\text{m}$, such as $20\mu\text{m}$ to $30\mu\text{m}$.

In the next step the polymer fragments are washed to remove the template molecules. This may be achieved by contacting the polymer fragments with a cleaning solution and stirring and agitating the solution. The cleaning solution is selected according to the particular template molecule. The template molecule should typically have good solubility in the cleaning solution. The cleaning solution may be water or may be an organic solvent. The washing step may be repeated until substantially all the template molecules on the surface of the polymer fragments have been removed. A number of different cleaning solutions may be used during the washing step. The washed polymer fragments may be dried, if desired, in any suitable manner.

Functionalised moiety

As previously mentioned, the process of the present invention comprises the step of grafting a chemical species selected from a molecularly imprinted polymer and a functionalised moiety onto the porous substrate.

The functionalised moiety is preferably a hydrocarbyl functionalised moiety.

As used herein, the term "hydrocarbyl" refers to a group comprising at least C and H that may optionally comprise one or more other suitable substituents. Examples of such substituents may include halo-, alkoxy-, nitro-, an alkyl group, or a cyclic group. In addition to the possibility of the substituents being a cyclic group, a combination of substituents may form a cyclic group. If the hydrocarbyl group comprises more than one C then those carbons need not necessarily be linked to each other. For example, at least two of the carbons may be linked *via* a suitable element or group. Thus, the hydrocarbyl group may contain heteroatoms. Suitable heteroatoms will be apparent to those skilled in the art and include, for instance, sulphur, nitrogen, oxygen, silicon and phosphorus.

Preferably the functionalised moiety comprises a cyclic group.

The term "cyclic group" as used herein means atoms bonded in a closed ring system. The cyclic group may be a homocyclic group or a heterocyclic group. Preferably the cyclic group is a homocyclic group.

Preferably the functionalised moiety comprises an aromatic group.

The term "aromatic group" as used herein means a cyclically conjugated molecular entity with a stability due to delocalisation greater than that of the hypothetical localised structure.

In a preferred aspect, the functionalised moiety comprises a phenylene group.



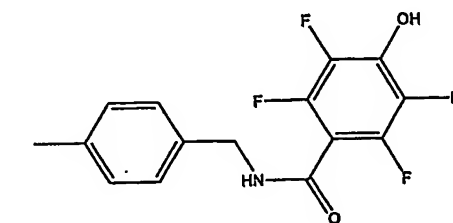
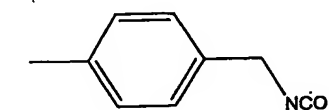
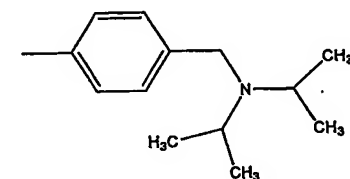
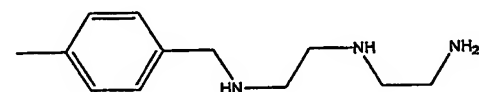
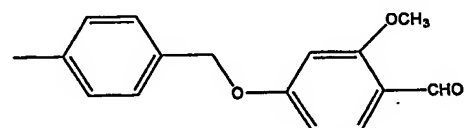
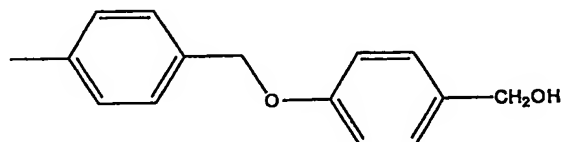
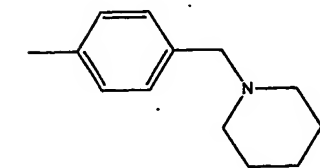
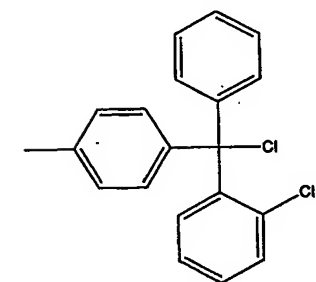
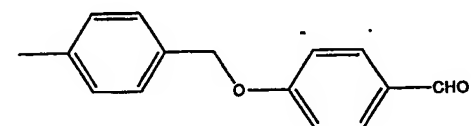
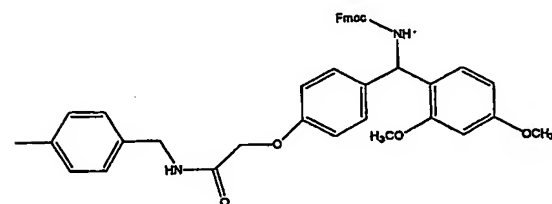
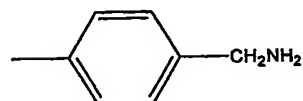
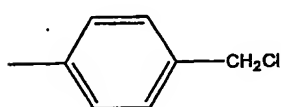
Phenylene Group

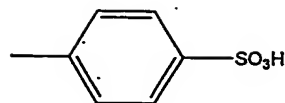
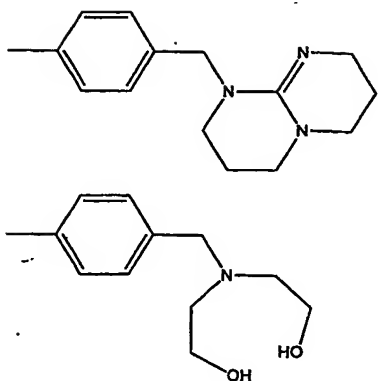
Preferably the functionalised moiety comprises a $-\text{C}_6\text{H}_4\text{-CH}_2\text{-}$ group.

In a preferred aspect, the functionalised moiety comprises a functional group selected from the group consisting of an alcohol, an aldehyde, an amide, an amine, an ether, a halogen, an isocyanate and a sulphonic acid. Preferably selected from the group consisting of an alcohol, an amine and an ether.

In a preferred aspect, the functional group of the functionalised moiety is not bonded directly to the porous substrate during the grafting step. In a preferred aspect, a carbon atom of the functionalised moiety is directly bonded to the porous substrate during the grafting step. Preferably a phenylene group of the functionalised moiety is directly bonded to the porous substrate during the grafting step.

Examples of suitable functionalised moieties include:





Grafting

- Prior to grafting, the external surface and/or internal surface of the porous substrate is typically activated. Activation methods include plasma treatment, corona discharge, oxidising chemicals, ultra-violet irradiation and other forms of radiation treatment. Activation may increase the surface concentration of the chemical species that are grafted.
- 10 The chemical species of the present invention may be grafted onto the porous substrate using any suitable technique. For example, standard chemistry techniques such as solution phase polymerisation. Preferred, however is the solvent-less plasma polymerisation technique.
 - 15 Preferably, the chemical species is grafted using plasma polymerisation.

In one aspect, preferably the polymer components are a polymer powder and the chemical species is grafted using pulsed plasma polymerisation.

- 20 In another aspect, preferably the chemical species is a functionalised moiety and the chemical species is grafted using pulsed plasma polymerisation.

In another aspect the chemical species is grafted using pulsed plasma polymerisation.

- 25 Plasma polymerisation is typically carried out in a reactor, such as in an inductively coupled cylindrical glow discharge reactor. The porous substrate is placed in the reactor and is contacted with reactive gas-phase radicals. The radicals typically form covalent

bonds with the porous substrate and are thus grafted to the substrate. The radicals are typically generated from a source gas, in a non-equilibrium, low pressure environment, and delivered to the porous substrate by at least one of convective and diffusional transport. The radicals are generated from the source gas by exposing the source gas to radical forming conditions as created by, for example, a radiofrequency (RF), microwave or direct current discharge (any of which will create a gas plasma discharge), laser sustained discharges, UV laser photolysis, high-powered UV/VUV lamp driven photolysis, high energy electron beams, and other high-intensity ionising or radical forming radiation sources. While any of these radical forming conditions may be used to generate the reactive radicals, gas plasma discharge is a preferred technique. Generation of the gas plasma discharge by a pulsed radiofrequency is particularly preferred.

A plasma polymerisation process is environmentally advantageous because it uses minimal amounts of energy and raw materials to effect the grafting and the functionalisation is typically substantially uniform throughout the porous substrate. A plasma polymerisation process is particularly advantageous if the chemical species to be grafted is in short supply, for example due to cost factors or difficulty of synthesis, since there is minimal wastage of the chemical species using this technique.

Pulsed plasma polymerisation provides further advantages over plasma polymerisation. The use of pulsed plasma polymerisation typically reduces the fragmentation and structural rearrangement of the chemical species during grafting, resulting in greater structure retention. Pulsing the plasma provides a less energetic deposition process, which allows the polymerisation to occur with much less degradation than when using continuous plasma. Radio frequency pulsing is the preferred method of achieving this.

Without wishing to be bound by theory, it is believed that pulsing the electrical discharge on the microsecond-millisecond time scale enables conventional polymerisation reaction pathways to proceed during the duty cycle off-period. This leads to a reduction in the structural rearrangement and minimises damage to the chemical species yet to be grafted and those already grafted onto the porous substrate.

As previously mentioned, the porous substrate comprises a body having an external surface and pores extending from the external surface into the body, wherein the pores define an internal surface.

- 5 Preferably the chemical species is grafted onto the external surface and onto the internal surface of the porous substrate.

More preferably the chemical species is grafted substantially uniformly throughout the porous substrate.

10

In a highly preferred aspect, the number of grafted chemical species per unit area on the external surface is approximately equal to the number of grafted chemical species per unit area on the internal surface. A relative measure of the amount of functionality that has been imparted to the surface of the porous substrate may be obtained by using any
15 of x-ray photoelectron spectroscopy (XPS), infrared spectroscopy or chemical analysis.

For many applications, the functionalised porous material is useful because the initially produced functionality (e.g. amino or hydroxyl groups) provides chemical handles which may be elaborated into bio-molecules and other application-specific chemical groups.

20

The present invention also provides a functionalised porous material obtained or obtainable by the process of the invention.

FUNCTIONALISED POROUS MATERIAL

25

As previously mentioned, in one aspect, the present invention provides a functionalised porous material comprising a porous substrate comprising a body having an external surface and pores extending from the external surface into the body, wherein the pores define an internal surface and a molecularly imprinted polymer; wherein the molecularly
30 imprinted polymer is attached to the external surface and/or the molecularly imprinted polymer is attached to the internal surface of the porous substrate.

The term "attached" as used herein means linked by a covalent bond.

35

Molecularly Imprinted Polymer

Preferably the molecularly imprinted polymer is as described herein.

- 5 Preferably the molecularly imprinted polymer is attached to the external surface and the internal surface of the porous substrate.

In one preferred aspect, the molecularly imprinted polymer is synthesised *in situ*.

- 10 As previously mentioned, the first step in the production of a molecularly imprinted polymer typically involves the provision of a reaction mixture comprising monomer units and a template molecule. A molecularly imprinted polymer may be synthesised *in situ* by any suitable method. For example, a molecularly imprinted polymer may be synthesised *in situ* by attaching one or more of the monomer units to the porous substrate by plasma
15 polymerisation (deposition) or any other suitable method. The template may then adhere to the attached monomer unit(s) and the remaining monomer units could then be introduced. Polymerisation of the monomer units could then be effected and the template could then be removed, for example by washing, leaving the molecularly imprinted polymer attached to the porous substrate.

20

Preferably the molecularly imprinted polymer is synthesised using plasma polymerisation. More preferably, the molecularly imprinted polymer is synthesised using pulsed plasma polymerisation.

- 25 In another preferred embodiment, the molecularly imprinted polymer is grafted onto the porous substrate.

In this aspect, the molecularly imprinted polymer is preferably produced using any of the methods described herein.

30

Preferably the molecularly imprinted polymer is grafted using plasma polymerisation. More preferably, the molecularly imprinted polymer is grafted using pulsed plasma polymerisation.

In a preferred aspect, the molecularly imprinted polymer is capable of interacting with a species selected from the group consisting of a metal ion, a toxin, a pharmaceutical compound, or a microbial organism. Preferably the molecularly imprinted polymer is capable of interacting with a microbial organism.

5

Preferably the molecularly imprinted polymer is capable of immobilising a species selected from the group consisting of a metal ion, a toxin, a pharmaceutical compound, or a microbial organism. Preferably the molecularly imprinted polymer is capable of immobilising a microbial organism.

10

RF Tag

In one preferred aspect, the functionalised porous material of the present invention comprises an RF tag.

15

A radiofrequency tag (RF tag) is a glass encased microchip that can be read by a reader. Other readable devices may also be used in the present invention as alternatives to RF tags. Suitable readable devices may be obtained from Innovision Research & Technology, Ash Court, 23 Rose St., Wokingham, Berkshire, RG40 1XS, UK.

20

Incorporation of an RF tag in the functionalised porous material of the present invention may enable the tracking of specific complex reaction pathways amongst a number of such reactions occurring in parallel.

25

For example a functionalised porous material (FPM) comprising an RF tag could be used in the synthesis of a combinatorial library. Each unique FPM can be tagged with an RF tag having a unique identifier code. A divide, track and apportion procedure may be utilised in this synthetic strategy. Initially, a large quantity of RF tagged FPMs suitable for solid phase synthesis are prepared. The FPMs are then divided evenly into the number of reaction vessels required to couple each monomer in the library repertoire.

30

The reaction vessel location of each FPM is recorded via scanning of its RF transponder code. Redistribution of the FPMs is then guided by a computer database whereby the past and future reaction vessel locations of each FPM is recorded and determined, via scanning of the FPM's RF transponder code. By repeating this procedure throughout

each step of the library synthesis, a histogram of the synthesis may be developed in a database.

- The inert nature of the RF tag, a glass encased microchip, avoids the problematic side-reactions which are associated with the use of chemical tags. Furthermore, the transmission or retrieval of information from any functionalised porous material is instantaneous, avoiding the added reaction times associated with synthesising chemical tags.
- 10 Preferably the RF tag is incorporated in the functionalised porous material in a manner that enables the RF tag to be removed and reused. It is advantageous for the RF tags to be reusable because they are expensive. The RF tag may be incorporated during any of the process steps for the preparation of the functionalised porous material.
- 15 In a preferred aspect, the RF tag is incorporated after the sintering step (i). Preferably, the RF tag is incorporated in the porous substrate. In this aspect, the porous substrate may be formed or adapted to comprise a cavity into which the RF tag may be inserted. When the porous substrate is produced by sintering polymer components in a mould, the mould may be configured such that the porous substrate is formed comprising a cavity of
- 20 suitable dimensions for an RF tag to be inserted in it.

In another preferred embodiment, the RF tag is incorporated in the functionalised porous material. In this aspect, the functionalised porous material may be formed from a porous substrate that had been formed or adapted to comprise a cavity into which the RF tag

25 could be inserted. Alternatively, the functionalised porous material itself may have been adapted to comprise a cavity into which the RF tag could be inserted. The porous substrate or functionalised porous material may be adapted to comprise a cavity by any suitable means such as by mechanical means. The cavity could be created by cutting out part of the porous substrate or functionalised porous material.

30

Void Volume and Internal Surface Area

The void volume is defined as the volume within the porous substrate that would be accessible to a fluid that entered the porous substrate. Thus, the porosity may be

35 defined as the void volume divided by the total volume of the porous substrate.

The internal surface area may be measured by mercury intrusion porosimetry or gas adsorption such as BET (Brunauer, Emmett and Teller).

5 In one aspect, preferably the functionalised porous material has a low void volume.

In one aspect, preferably the functionalised porous material has a high void volume.

10 In one aspect, preferably the functionalised porous material has a low internal surface area.

In one aspect, preferably the functionalised porous material has a high internal surface area.

15 A preferred embodiment of the present invention is a functionalised porous material wherein the void volume is low and the internal surface area is high.

20 The low hold up volume, high level of activity and high degree of specificity afforded by this embodiment make it particularly suitable for sample preparation involving small quantities of analyte.

Another preferred embodiment of the present invention is a functionalised porous material wherein the void volume is high and the internal surface area is high.

25 The open structure of this embodiment makes it suitable for applications where high liquid flow or diffusion rates are important such as sensors, bio-reactors, filters or catalysis applications. A functionalised porous material of this type could advantageously be incorporated in a filtration device such that during its duty as a filter it also removes specific target species such as antigens. This is normally only possible
30 using a much finer filter media with all the consequent process restrictions such as higher operating pressures.

A further preferred embodiment of the present invention is a functionalised porous material wherein the void volume is high and the internal surface area is low.

The open structure of this embodiment together with its lower density of available sites make it particularly suitable for synthesis reactions where steric effects might be a problem.

5 In a preferred aspect the functionalised porous material is in the shape of a cylinder or a rectangular prism. Preferably in this aspect the porous substrate is in the shape of a cylinder or a rectangular prism. Preferably in this aspect, the polymer components are sintered in a mould, wherein the mould is in the shape of a cylinder or a rectangular prism.

10

Device

The functionalised porous material of the present invention may be advantageously incorporated in a device, such as a filtration device.

15

Thus, in one aspect, the present invention provides a device comprising a functionalised porous material as herein defined. Preferably the device is a filtration device. More preferably the device is a filtration device capable of filtering a target species such as an antigen.

20

Aspects of the invention are defined in the appended claims.

The present invention will now be described in further detail by way of example only with reference to the accompanying figure. Figure 1 is a scanning electron micrograph (SEM)
25 showing the internal structure of a porous substrate.

All publications mentioned in the above specification are herein incorporated by reference. Various modifications and variations of the described methods and system of the invention will be apparent to those skilled in the art without departing from the scope
30 and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in chemistry or related fields are intended to be within the scope of the
35 following claims.

CLAIMS

1. A process for the preparation of a functionalised porous material comprising the steps of:
 - 5 (i) sintering polymer components to provide a porous substrate; and
 - (ii) grafting a chemical species selected from
 - (a) a molecularly imprinted polymer; and
 - (b) a functionalised moietyonto the porous substrate to provide the functionalised porous material;
- 10 wherein when the polymer components are a polymer powder and the chemical species is a functionalised moiety, the chemical species is grafted using pulsed plasma polymerisation.
2. A process according to claim 1 wherein the polymer components are polyolefin
- 15 components.
3. A process according to claim 1 or 2 wherein the polymer components are polyethylene components.
- 20 4. A process according to any one of claims 1 to 3 wherein the polymer components are a polymer powder.
5. A process according to any one of the preceding claims wherein the polymer components are sintered in a mould.
- 25 6. A process according to any one of claims 1 to 3 wherein the polymer components are polymer fibres.
7. A process according to any one of the preceding claims wherein the molecularly
- 30 imprinted polymer is capable of interacting with a species selected from the group consisting of a metal ion, a toxin, a pharmaceutical compound and a microbial organism.
8. A process according to any one of the preceding claims wherein the molecularly
- 35 imprinted polymer is capable of immobilising a species selected from the group consisting of a metal ion, a toxin, a pharmaceutical compound and a microbial organism.

9. A process according to any one of the preceding claims wherein the functionalised moiety comprises a cyclic group.
- 5 10. A process according to any one of the preceding claims wherein the functionalised moiety comprises an aromatic group.
11. A process according to any one of the preceding claims wherein the functionalised moiety comprises a phenylene group.
- 10 12. A process according to any one of the preceding claims wherein the functionalised moiety comprises a $-C_6H_4-CH_2-$ group.
13. A process according to any one of the preceding claims wherein the functionalised moiety comprises a functional group selected from the group consisting of an alcohol, an aldehyde, an amide, an amine, an ether, a halogen, an isocyanate and a sulphonic acid.
- 15 14. A process according to any one of the preceding claims wherein the functionalised moiety comprises a functional group selected from the group consisting of an alcohol, an amine and an ether.
- 20 15. A process according to any one of the preceding claims wherein the chemical species is grafted using plasma polymerisation.
- 25 16. A process according to any one of the preceding claims wherein the polymer components are a polymer powder and the chemical species is grafted using pulsed plasma polymerisation.
17. A process according to any one of the preceding claims wherein the chemical species is a functionalised moiety and the chemical species is grafted using pulsed plasma polymerisation.
- 30 18. A process according to any one of the preceding claims wherein the chemical species is grafted using pulsed plasma polymerisation.

19. A process according to any one of the preceding claims wherein the porous substrate comprises a body having an external surface and pores extending from the external surface into the body, wherein the pores define an internal surface and wherein the chemical species is grafted onto the external surface and onto the internal surface of the porous substrate.

20. A process according to claim 19 wherein the chemical species is grafted substantially uniformly throughout the porous substrate.

21. A process according to claim 19 or 20 wherein the number of grafted chemical species per unit area on the external surface is approximately equal to the number of grafted chemical species per unit area on the internal surface.

22. A functionalised porous material obtained by the process of any one of claims 1 to 21.

23. A functionalised porous material obtainable by the process of any one of claims 1 to 21.

24. A functionalised porous material comprising:

- (i) a porous substrate comprising a body having an external surface and pores extending from the external surface into the body, wherein the pores define an internal surface; and
- (ii) a molecularly imprinted polymer

wherein the molecularly imprinted polymer is attached to the external surface and/or the molecularly imprinted polymer is attached to the internal surface of the porous substrate.

25. A functionalised porous material according to claim 24, wherein the molecularly imprinted polymer is attached to the external surface and the internal surface of the porous substrate.

26. A functionalised porous material according to claim 24 or 25 wherein the molecularly imprinted polymer is synthesised *in situ*.

27. A functionalised porous material according to claim 26 wherein the molecularly imprinted polymer is synthesised using plasma polymerisation.

28. A functionalised porous material according to claim 26 or 27 wherein the molecularly imprinted polymer is synthesised using pulsed plasma polymerisation.

5 29. A functionalised porous material according to claim 24 or 25 wherein the molecularly imprinted polymer is grafted onto the porous substrate.

30. A functionalised porous material according to claim 29 wherein the molecularly imprinted polymer is grafted using plasma polymerisation.

10

31. A functionalised porous material according to claim 29 or 30 wherein the molecularly imprinted polymer is grafted using pulsed plasma polymerisation.

15 32. A functionalised porous material according to any one of the preceding claims wherein the molecularly imprinted polymer is capable of interacting with a species selected from the group consisting of a metal ion, a toxin, a pharmaceutical compound, or a microbial organism.

20 33. A functionalised porous material according to any one of the preceding claims wherein the molecularly imprinted polymer is capable of immobilising a species selected from the group consisting of a metal ion, a toxin, a pharmaceutical compound, or a microbial organism.

25 34. A functionalised porous material according to claim 32 or 33 wherein the species is a microbial organism.

35. A functionalised porous material according to any one of claims 22 to 34 comprising an RF tag.

30 36. A functionalised porous material according to any one claims 22 to 35 wherein the void volume is low.

37. A functionalised porous material according to any one of claims 22 to 35 wherein the void volume is high.

38. A functionalised porous material according to claims 36 or 37 wherein the internal surface area is high.
39. A functionalised porous material according to claim 37 wherein the internal surface
5 area is low.
40. A functionalised porous material according to any one of claims 22 to 39 wherein the functionalised porous material is in the shape of a cylinder or a rectangular prism.
- 10 41. A process substantially as hereinbefore described with particular reference to any one of the Examples.
42. A functionalised porous material substantially as hereinbefore described with particular reference to any one of the Examples.

ABSTRACT**PROCESS**

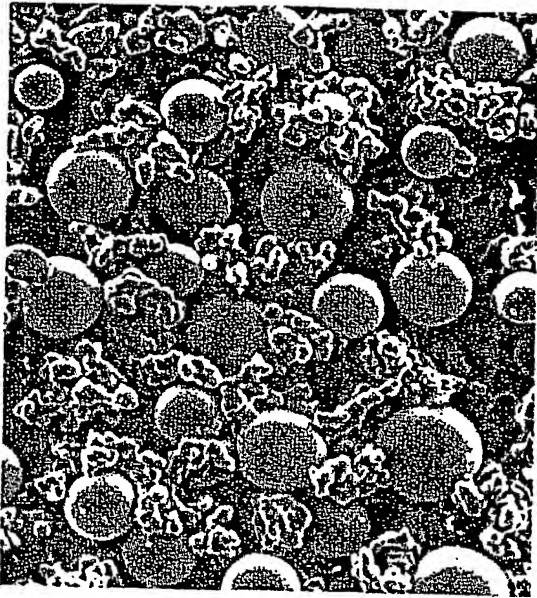
5

The present invention provides a process for the preparation of a functionalised porous material comprising the steps of sintering polymer components to provide a porous substrate and grafting a chemical species selected from a molecularly imprinted polymer and a functionalised moiety onto the porous substrate to provide the functionalised porous material; wherein when the polymer components are a polymer powder and the chemical species is a functionalised moiety, the chemical species is grafted using pulsed plasma polymerisation.

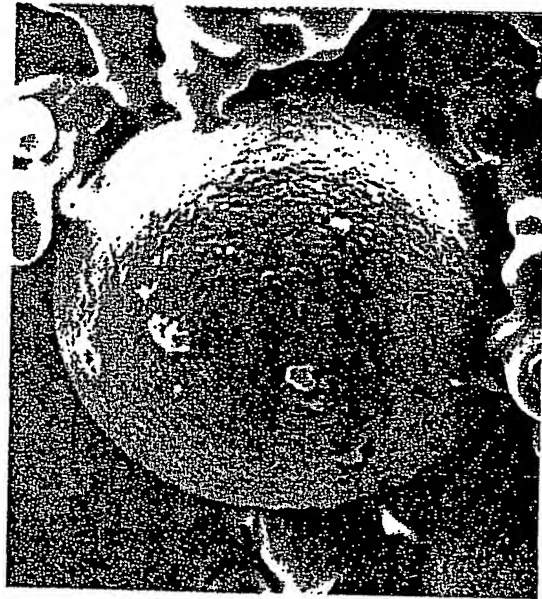
10



INTERNAL STRUCTURE



50 x Magnification



150 x Magnification

Figure 1

BEST AVAILABLE COPY

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

☒ **BLACK BORDERS**

☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**

☒ **FADED TEXT OR DRAWING**

☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**

☐ **SKEWED/SLANTED IMAGES**

☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**

☐ **GRAY SCALE DOCUMENTS**

☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**

☒ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**

☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.